Any pair of processor failures causes a system failure

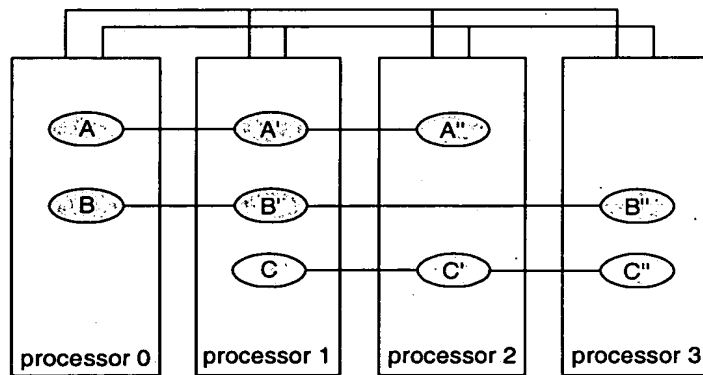**System Failure Modes**

Figure 1
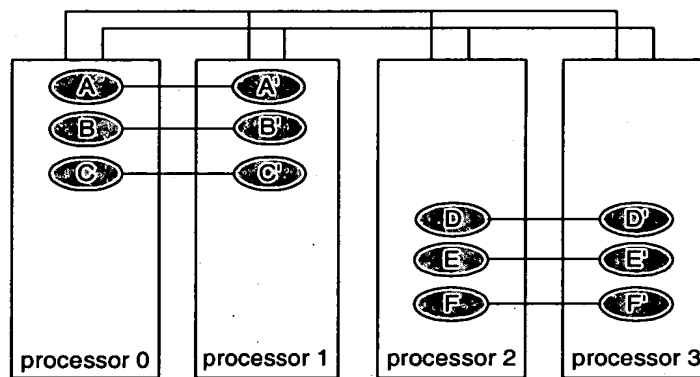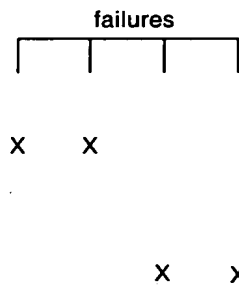
Only certain pairs of processor failures cause a system failure

Process Pairing

Figure 2

failures

X   X   X

X   X   X
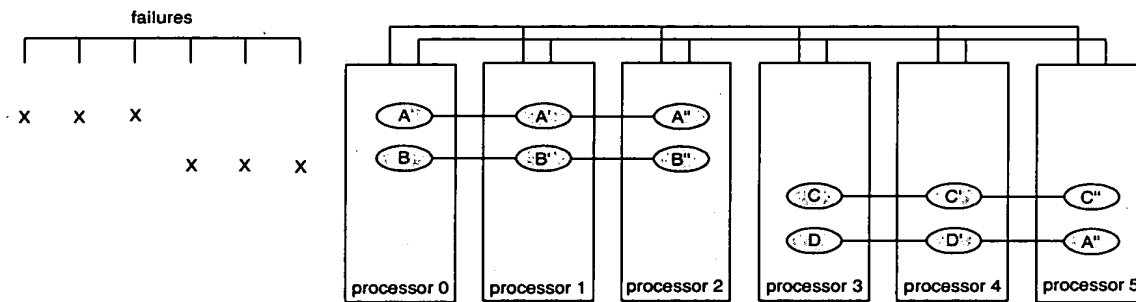
     X   X   X

processor 0   processor 1   processor 2   processor 3

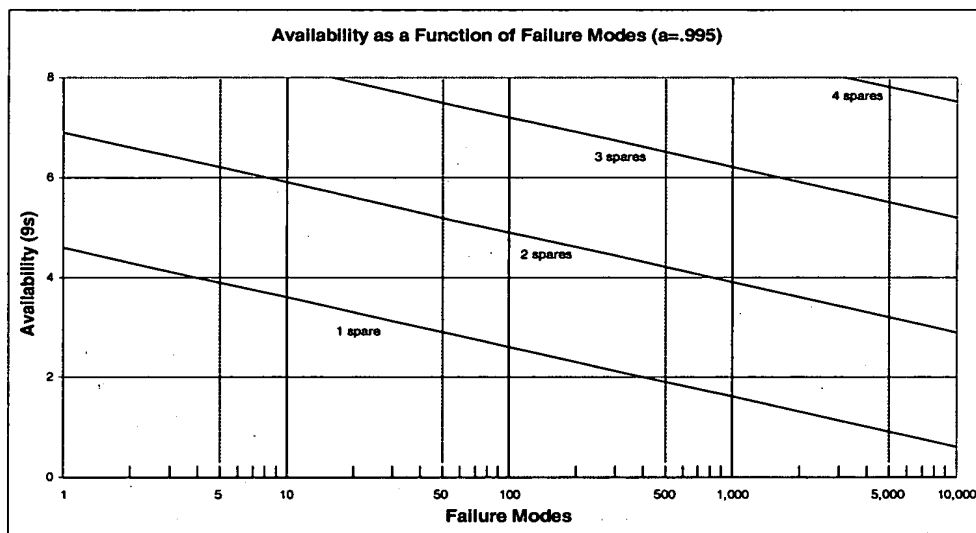Three processors must fail to cause a system failure

Double Sparing

Figure 3a

Only certain groupings of three processor failures cause a system failure

Process Tupling

Figure 3b

Availability as a Function of Failure Modes (a=.995)
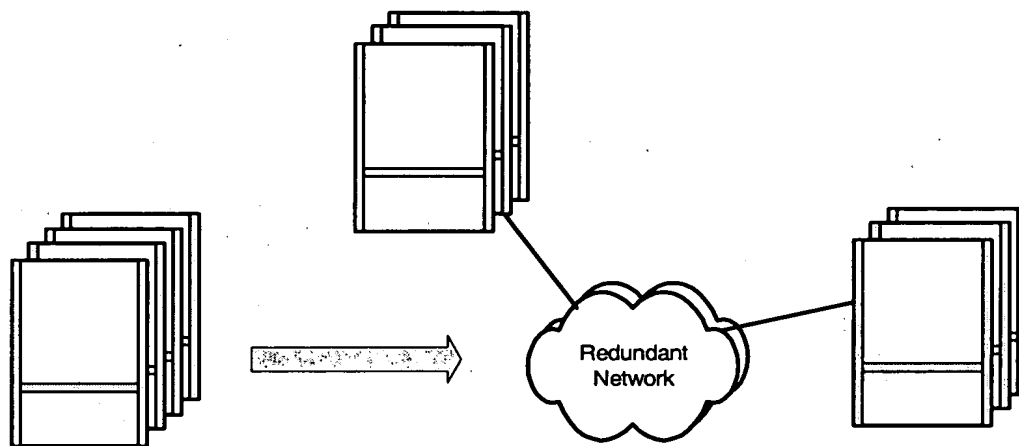
Failure Mode Impact on Availability

Figure 4
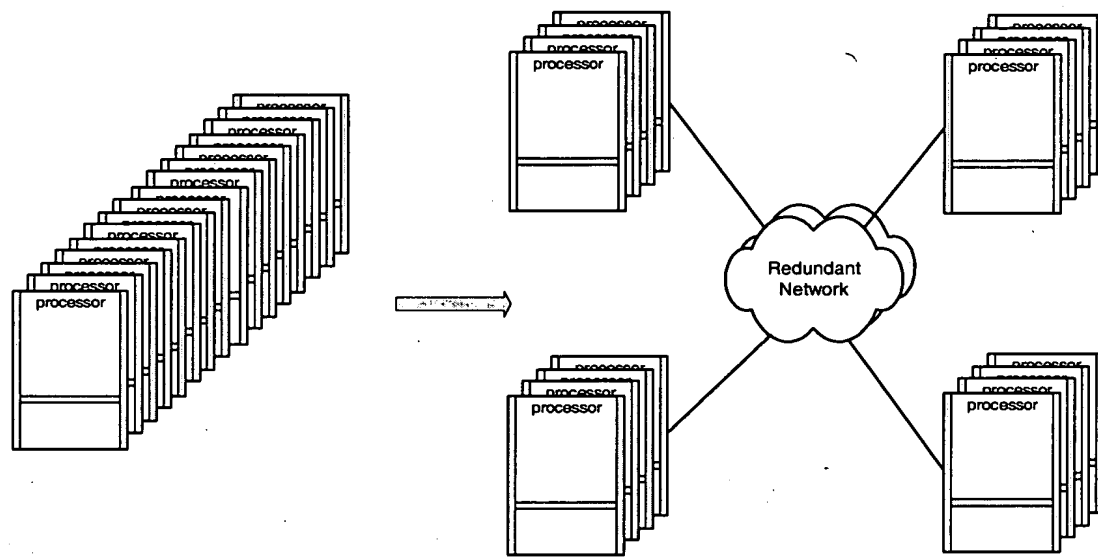
System Splitting

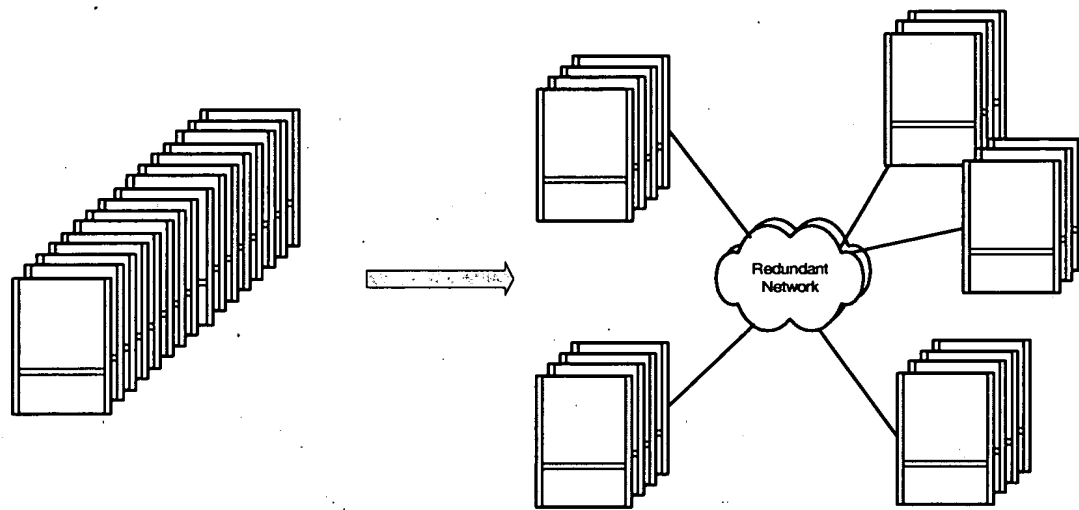**Figure 5a**

System Splitting with Capacity Enhancement

Figure 5b

Node Splitting

Figure 5c
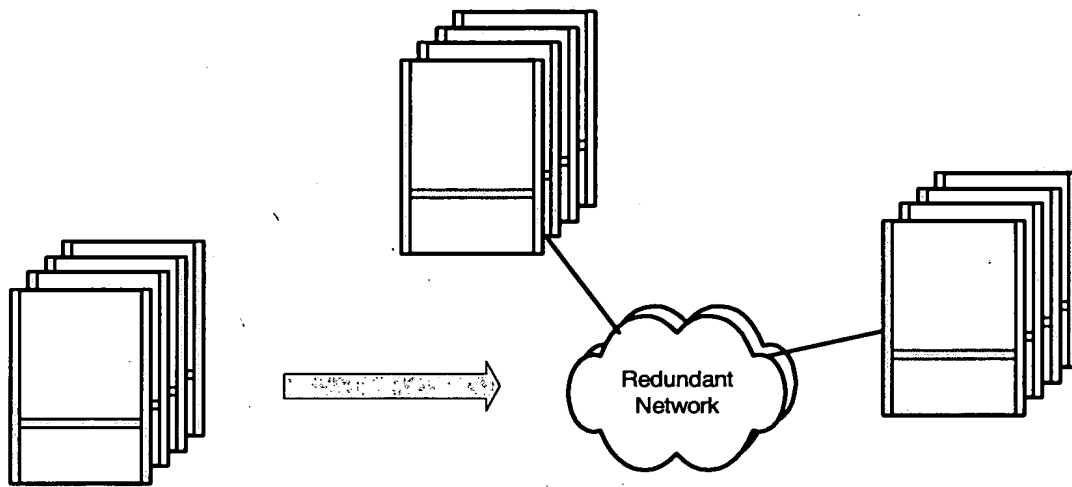
System Splitting with Full Redundancy

Figure 5d
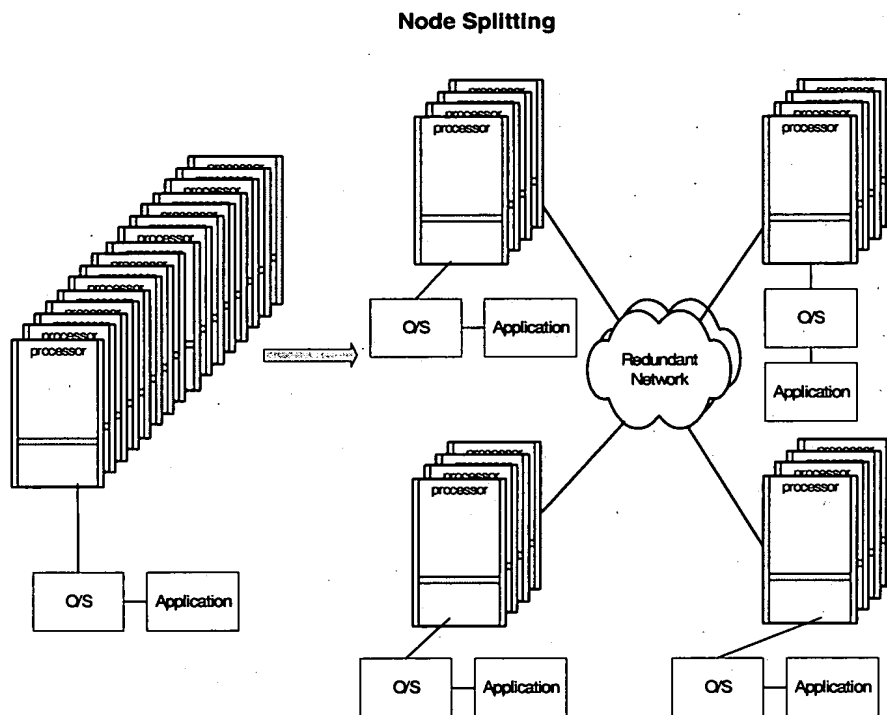
Node Splitting
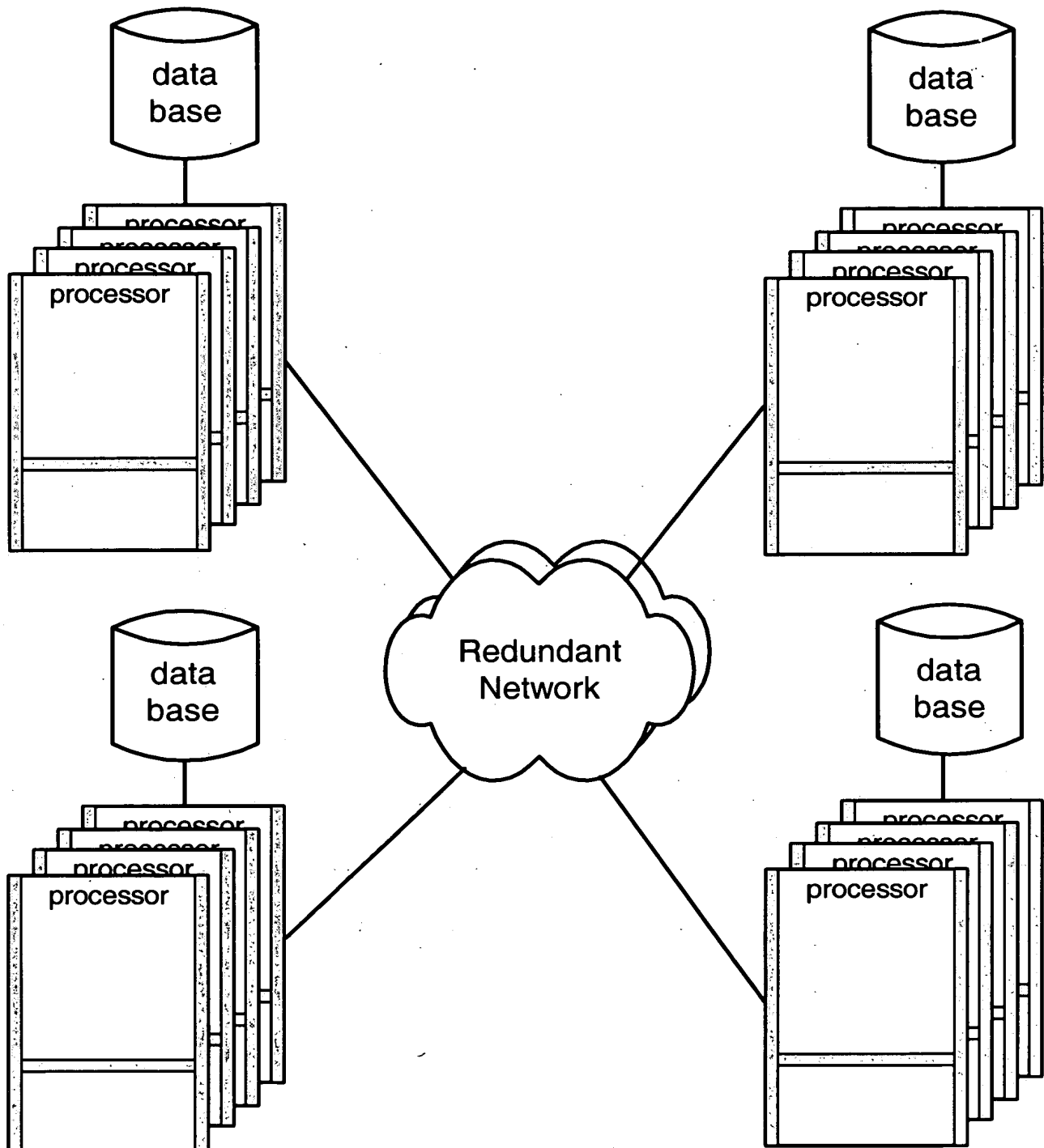
Figure 5e

Database on All Nodes

Figur 6
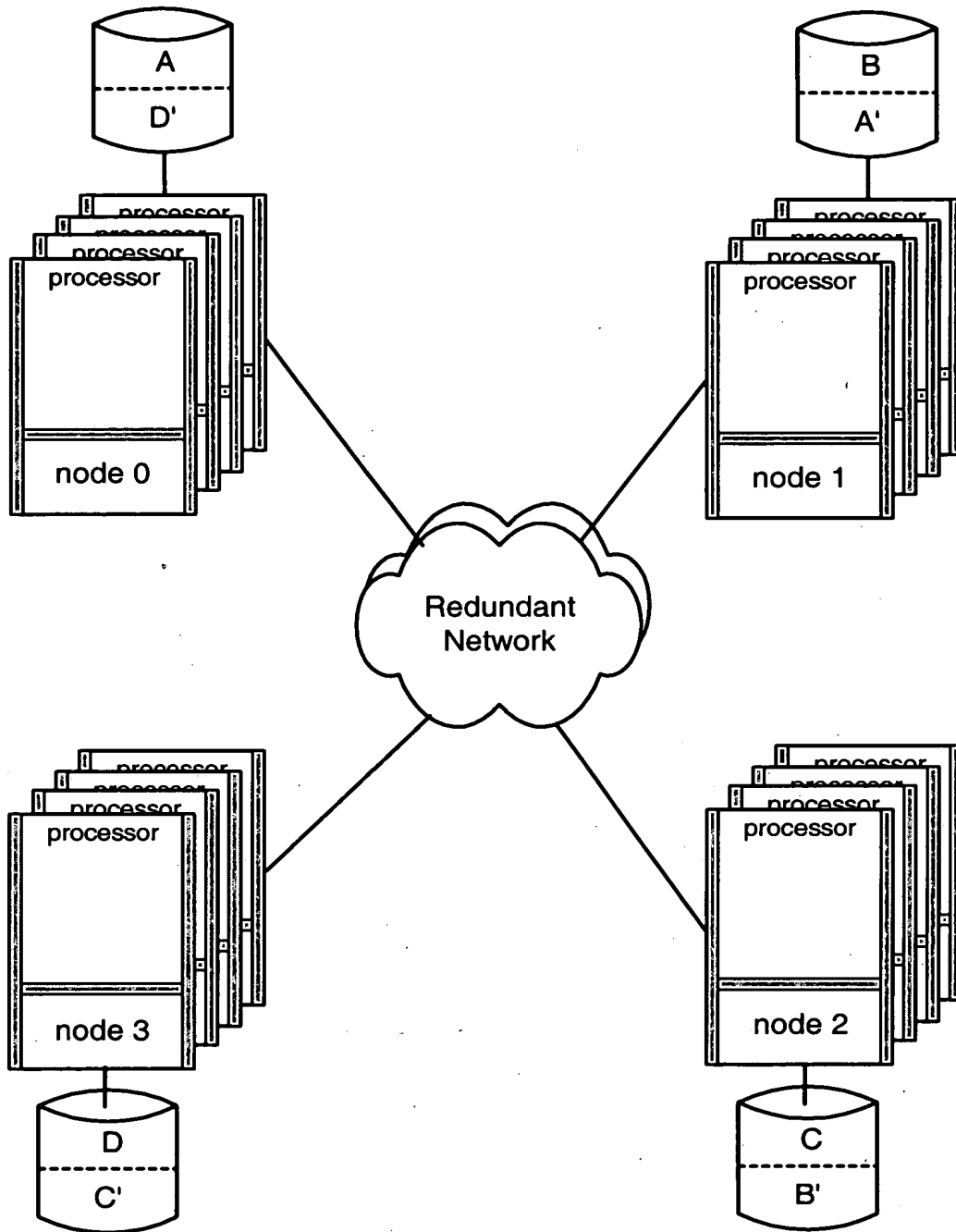
Partitioned Database

Figure 7
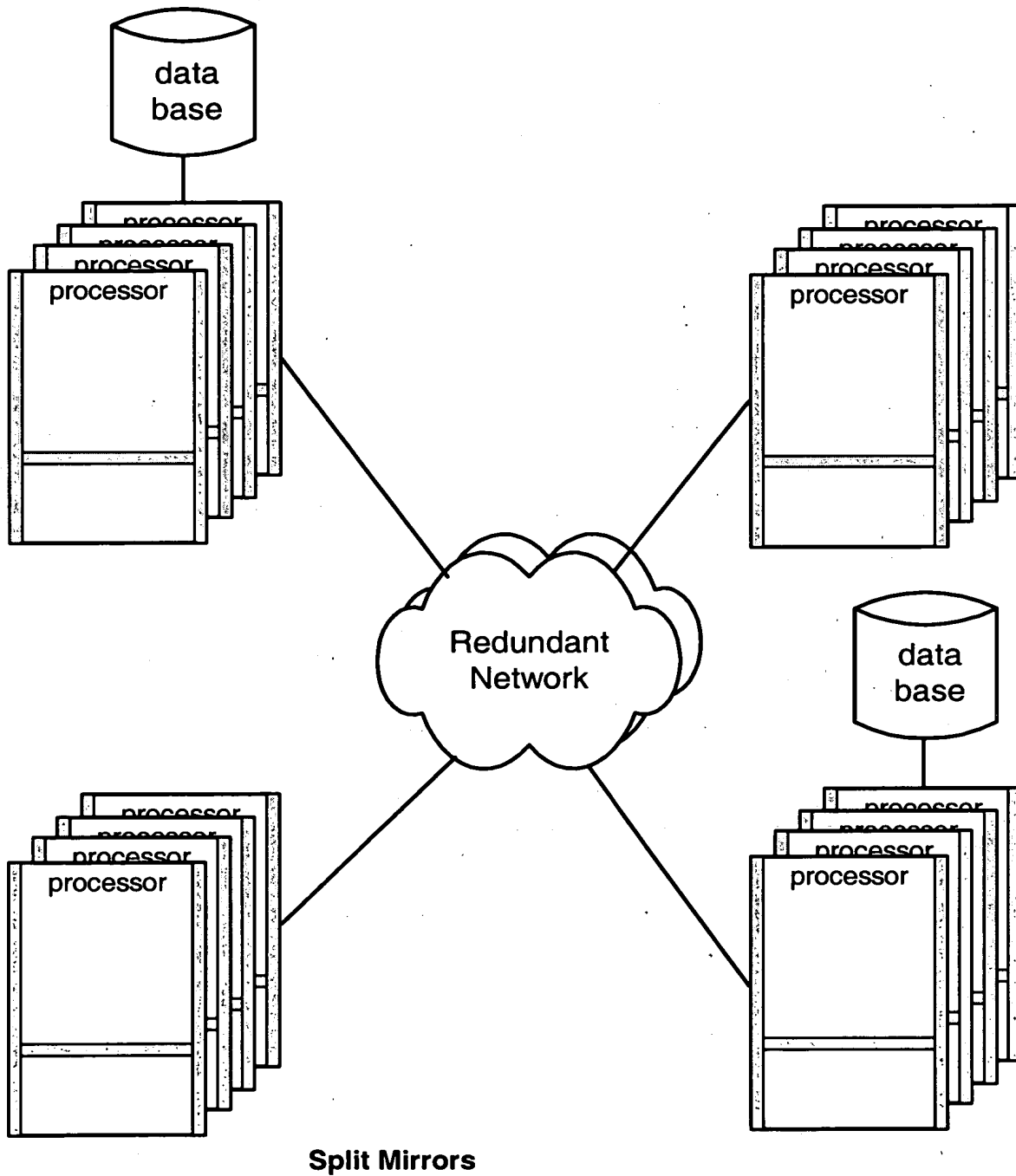
Split Mirrors
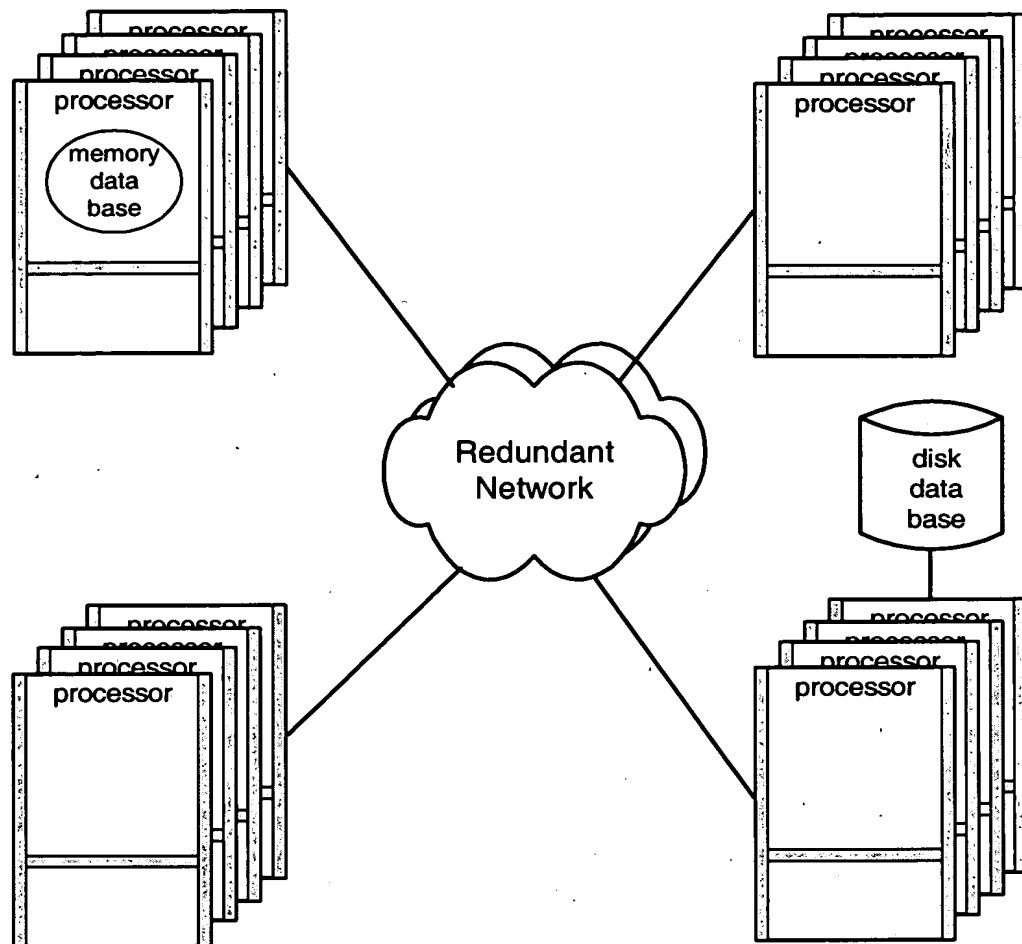
Figure 8a

Split Mirrors with Multiple Storage Media

Figure 8b

processor

processor

processor

processor

processor

data
base

data
base

processor

processor

processor

Redundant
Network
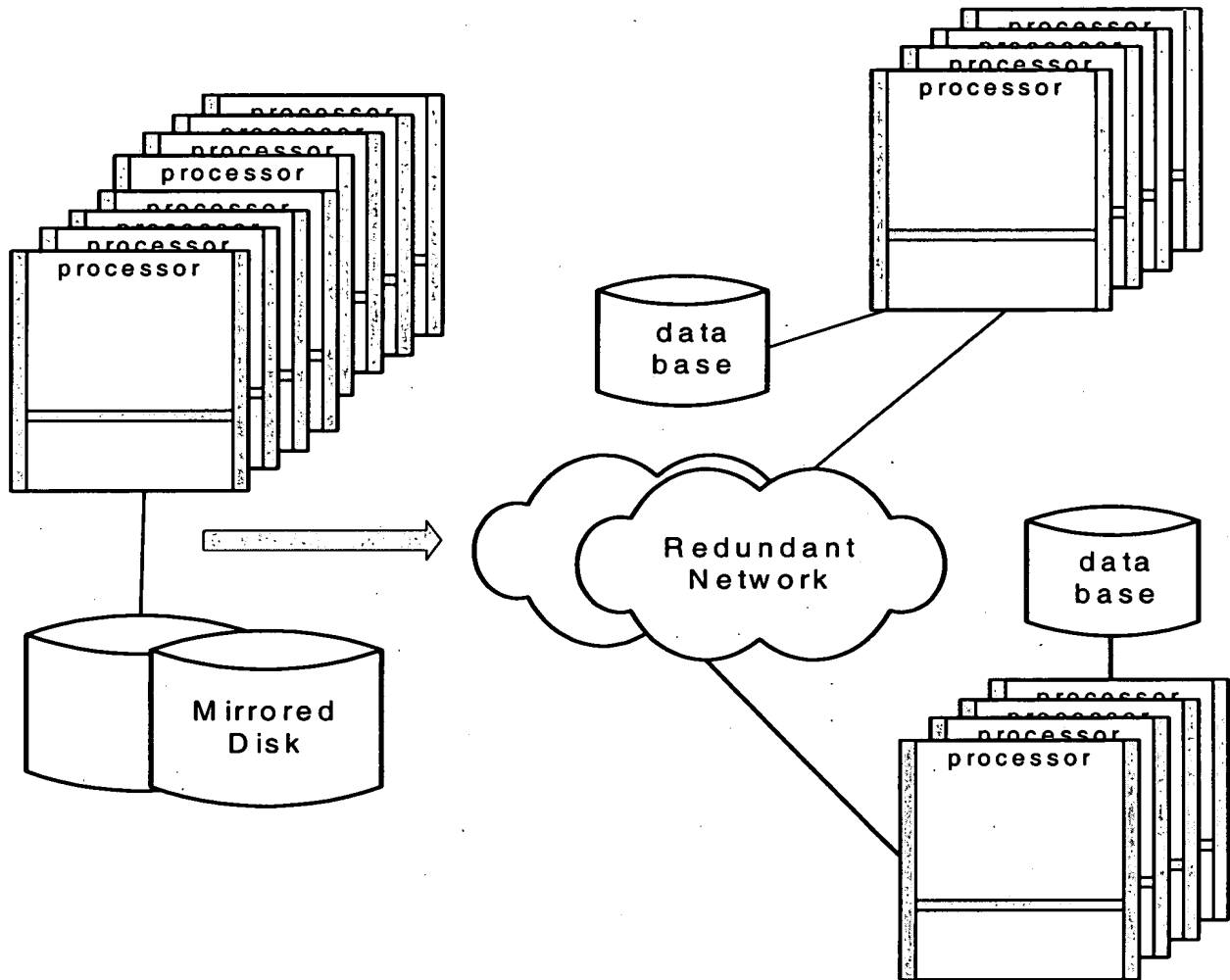
Mirrored
Disk

Splitting Mirrors

Figur 8c

Networked Database

Figure 9

Dual Writes

Figure 10

Asynchronous Data Replication

Figure 11

Synchronous Data Replication

Figure 12
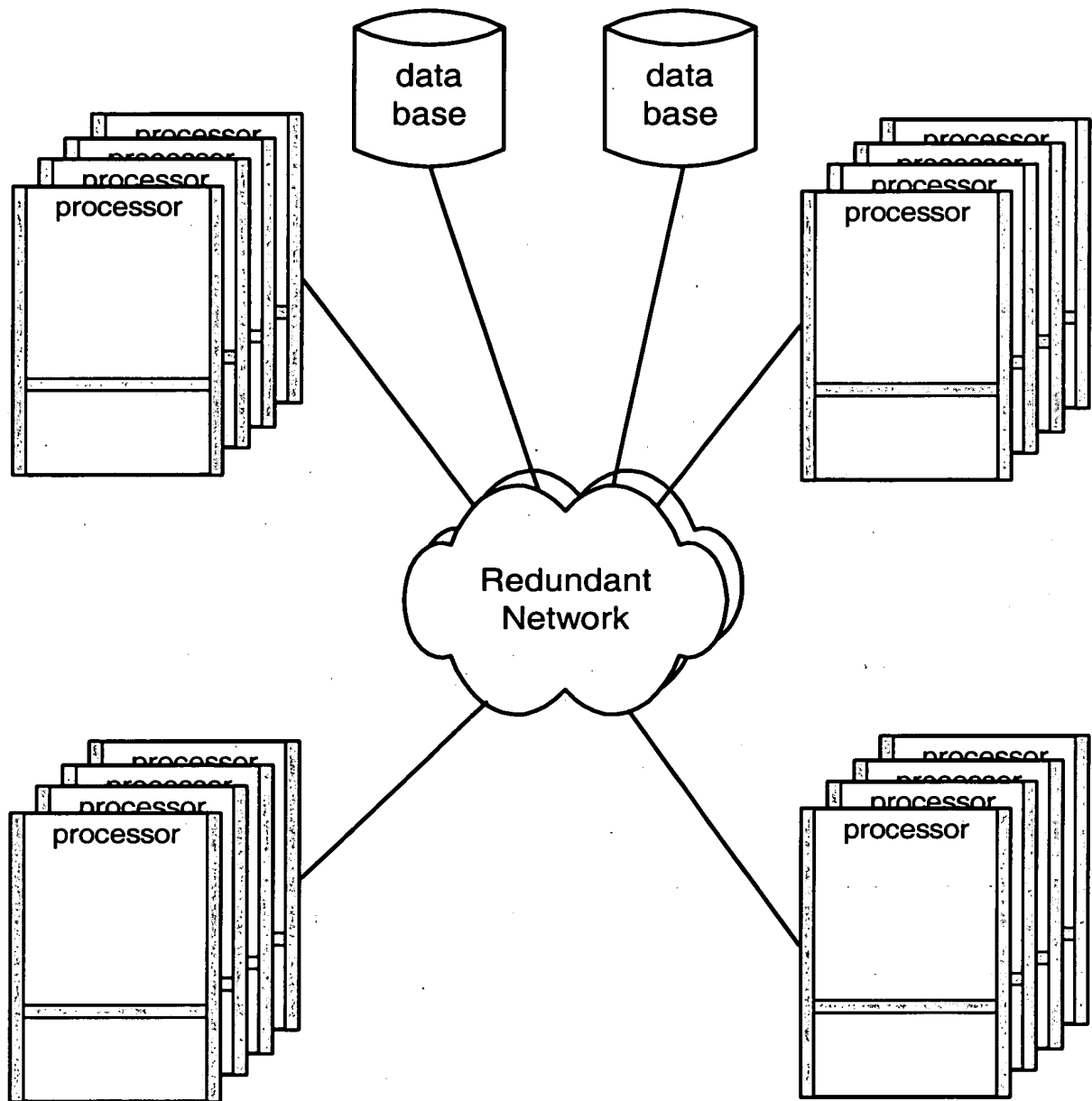
Distributed Network Storage

Figure 13

Fully Configured Split System

Figure 14

processor

processor

Redundant Network

processor

processor

Processing Nodes Only

Figure 15

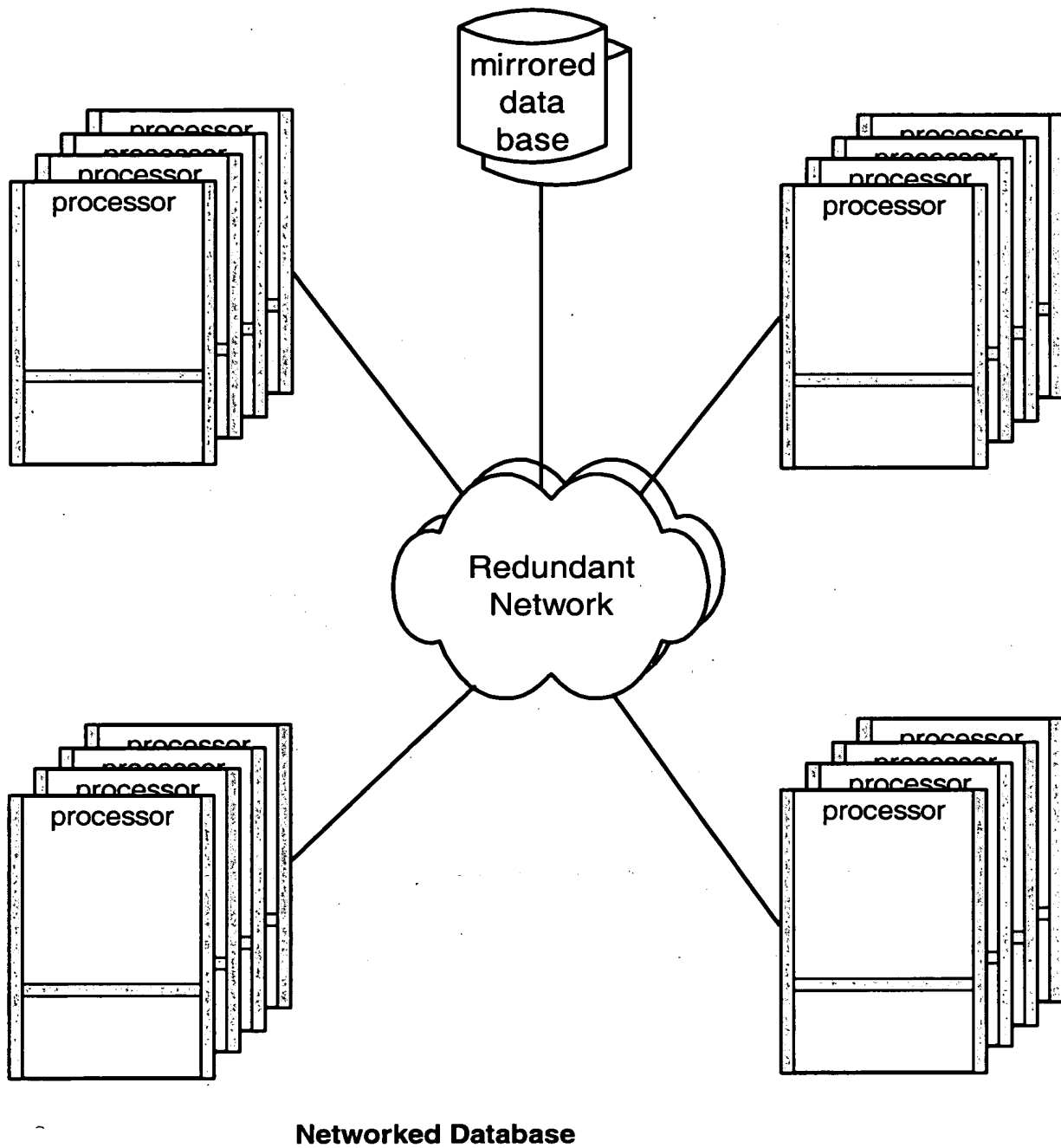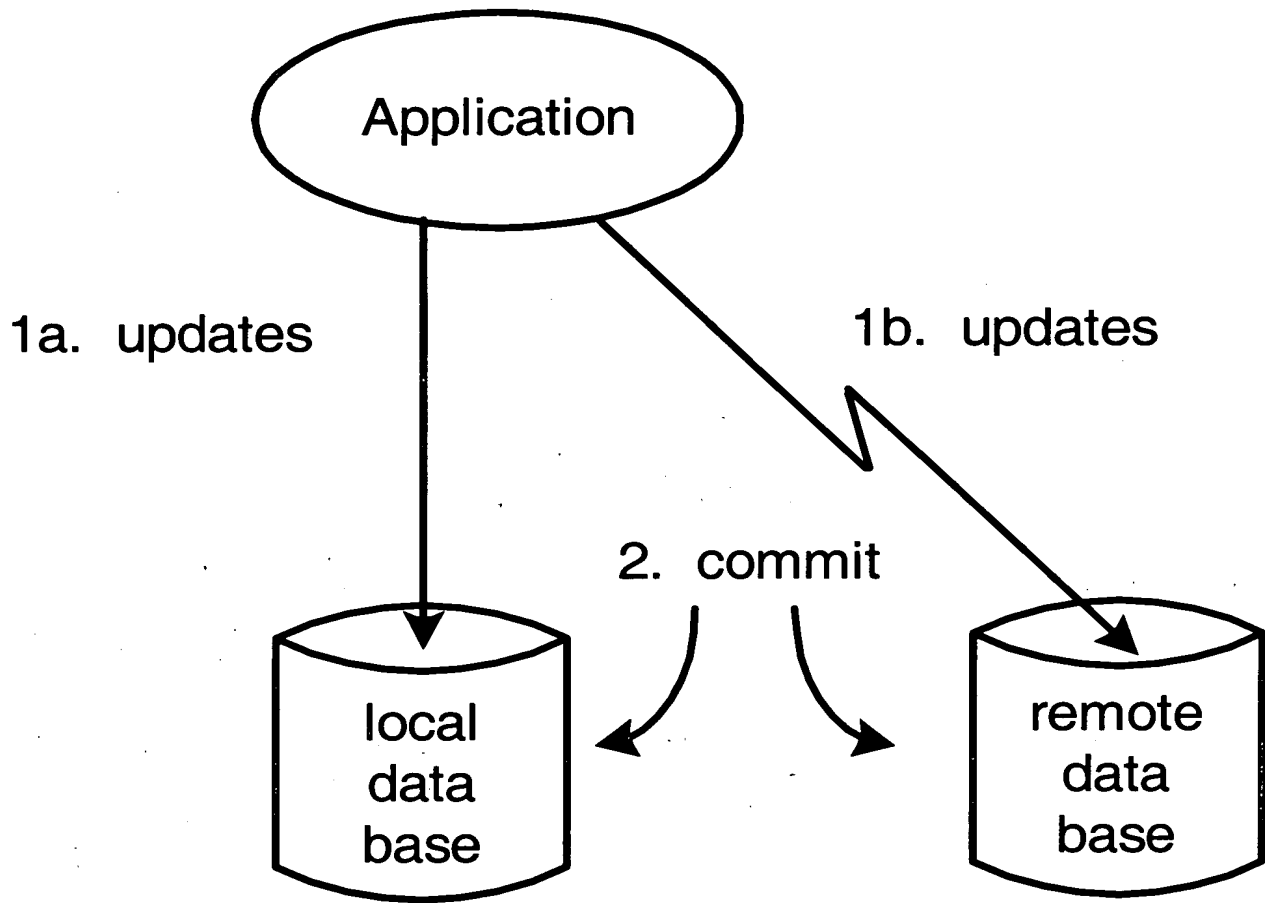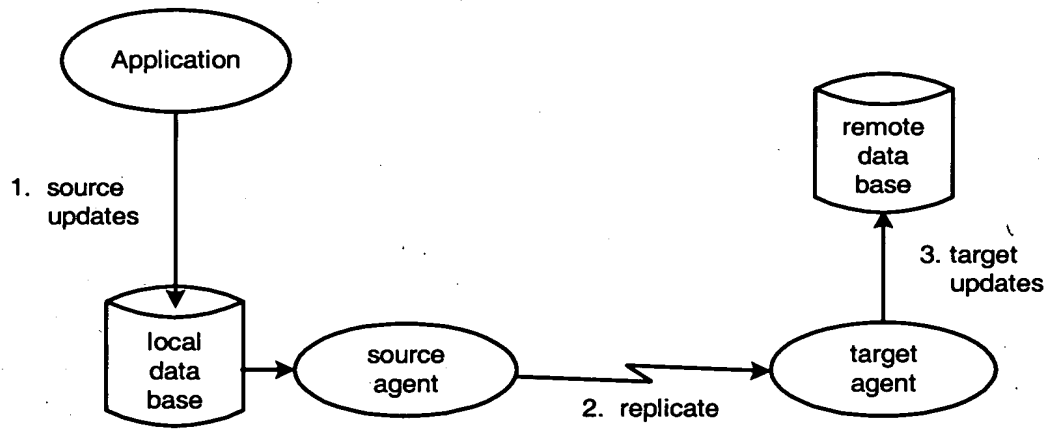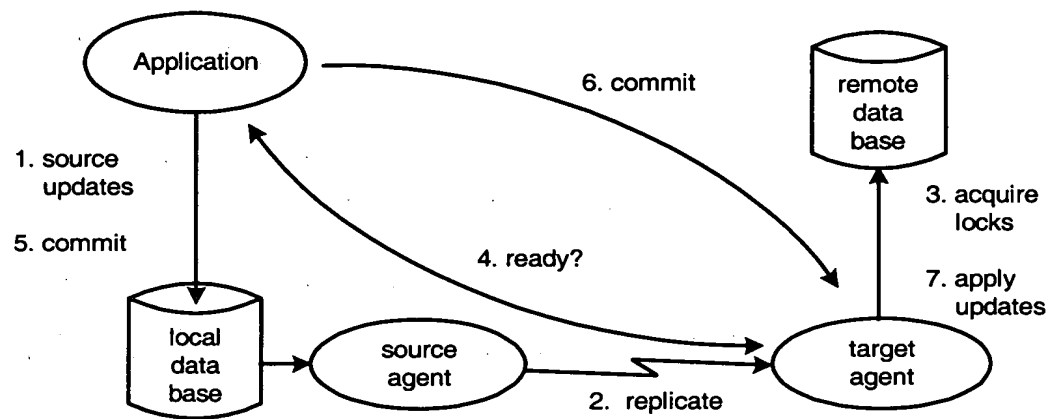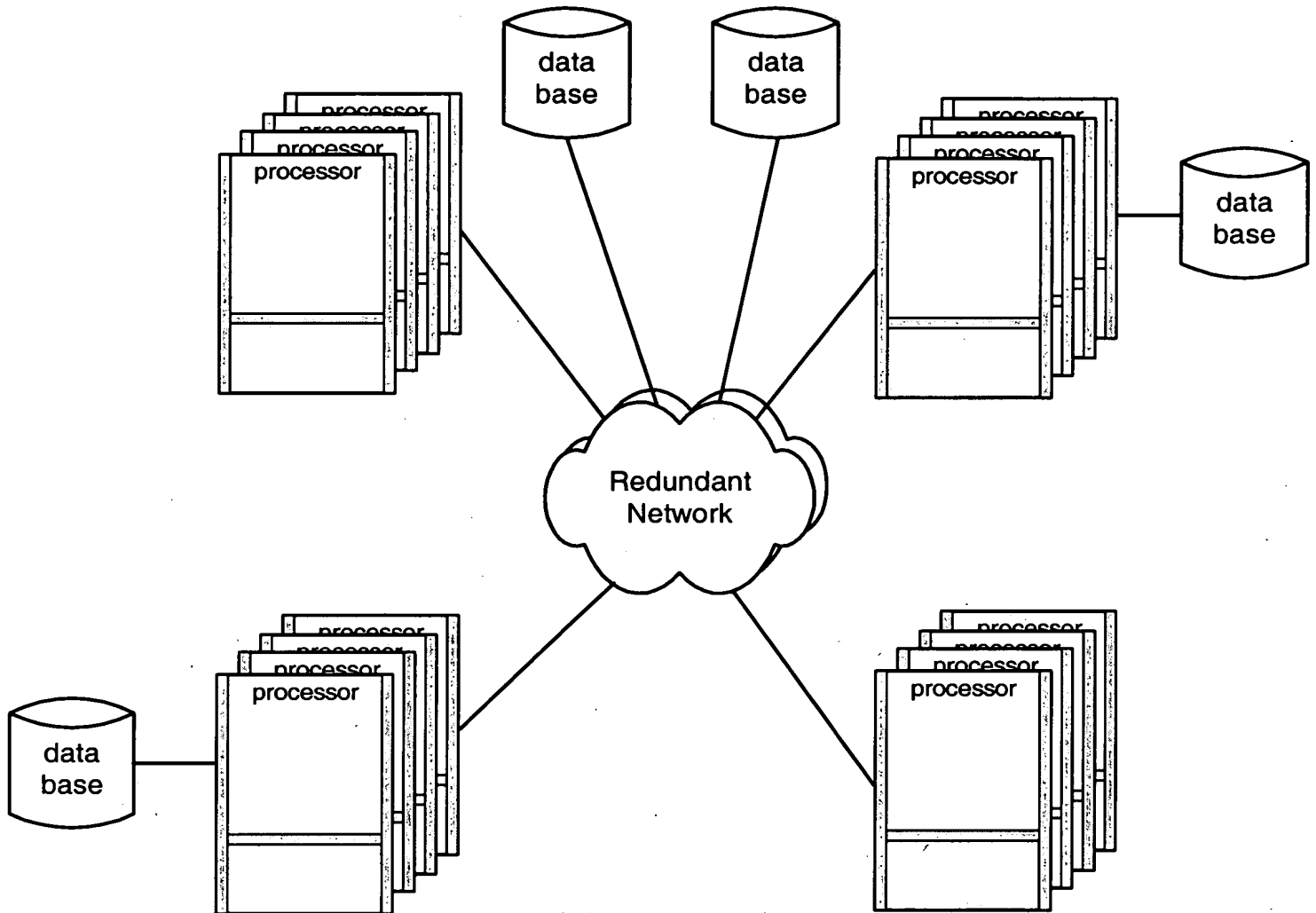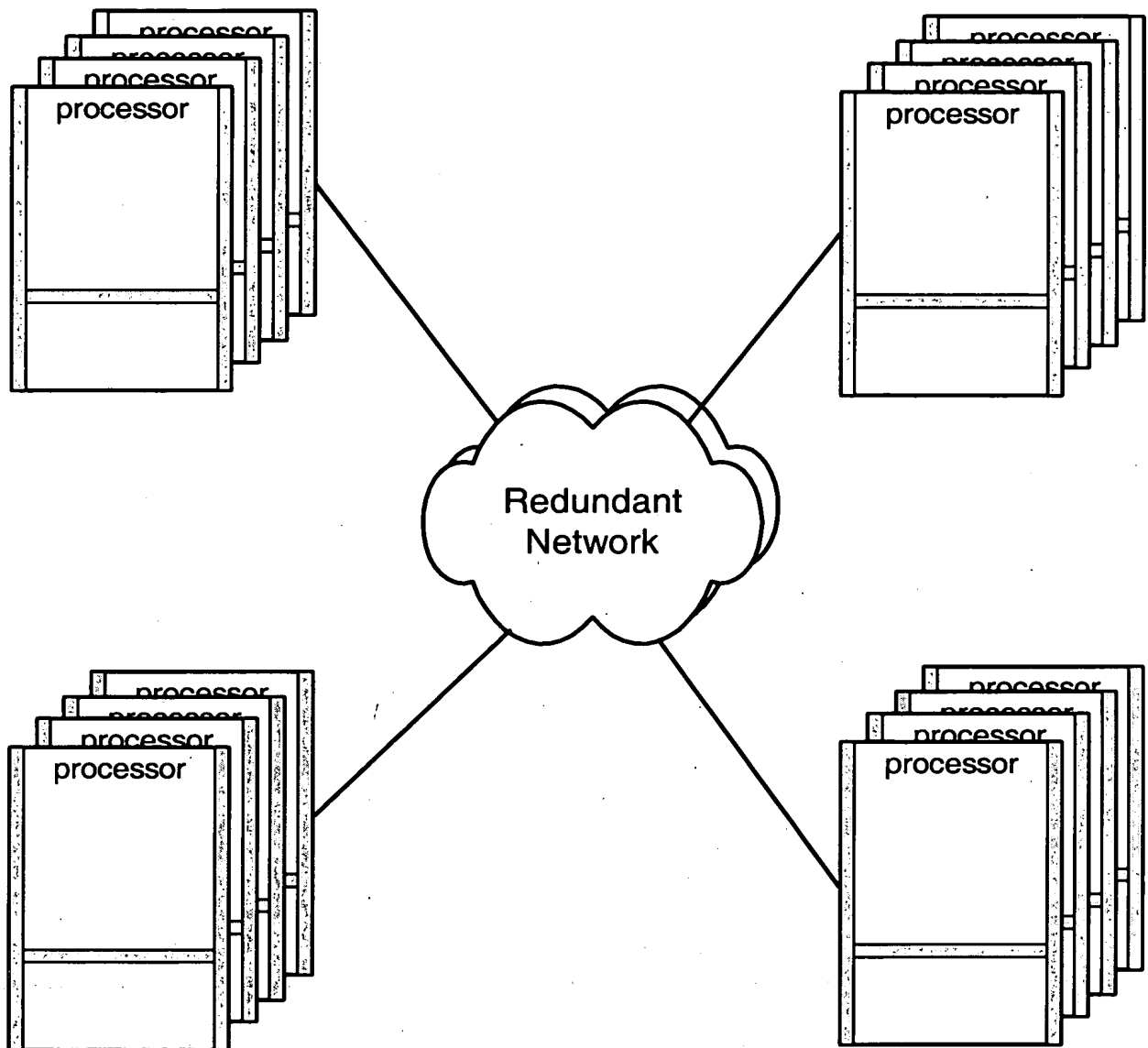| n	i	comb (n,i)	mode probability	s	A	F	approx F	% error (approx F high if > 0)
2	0	1	0.990025					
2	1	2	0.00995	0	0.990025	0.009975	0.01	0.25
2	2	1	0.000025	1	0.999975	0.000025	0.000025	0.00
4	0	1	0.980149501					
4	1	4	0.019701498	0	0.98015	0.019850499	0.02	0.75
4	2	6	0.000148504	1	0.999851	0.000149002	0.00015	0.67
4	3	4	4.975E-07	2	1	4.98125E-07	5E-07	0.38
4	4	1	6.25E-10	3	1	6.25E-10	6.25E-10	0.00
8	0	1	0.960693044					
8	1	8	0.038620826	0	0.960693	0.039306956	0.04	1.76
8	2	28	0.000679261	1	0.999314	0.000686131	0.0007	2.02
8	3	56	6.82674E-06	2	0.999993	6.8698E-06	7E-06	1.90
8	4	70	4.28815E-08	3	1	4.30544E-08	4.375E-08	1.62
8	5	56	1.72388E-10	4	1	1.72822E-10	1.75E-10	1.26
8	6	28	4.33136E-13	5	1	4.33758E-13	4.375E-13	0.86
8	7	8	6.21875E-16	6	1	6.22266E-16	6.25E-16	0.44
8	8	1	3.90625E-19	7	1	3.90625E-19	3.906E-19	0.00
16	0	1	0.922931124					
16	1	16	0.074205518	0	0.922931	0.077068876	0.08	3.80
16	2	120	0.00279669	1	0.997137	0.002863359	0.003	4.77
16	3	560	6.5584E-05	2	0.999933	6.66682E-05	7E-05	5.00
16	4	1820	1.0711E-06	3	0.999999	1.08413E-06	1.138E-06	4.92
16	5	4368	1.29177E-08	4	1	1.30376E-08	1.365E-08	4.70
16	6	8008	1.19008E-10	5	1	1.19867E-10	1.251E-10	4.39
16	7	11440	8.54326E-13	6	1	8.59178E-13	8.938E-13	4.02
16	8	12870	4.82973E-15	7	1	4.85138E-15	5.027E-15	3.63
16	9	11440	2.15734E-17	8	1	2.16494E-17	2.234E-17	3.21
b16	10	8008	7.58862E-20	9	1	7.60946E-20	7.82E-20	2.77
16	11	4368	2.08002E-22	10	1	2.08438E-22	2.133E-22	2.32
16	12	1820	4.35516E-25	11	1	4.3619E-25	4.443E-25	1.87
16	13	560	6.73391E-28	12	1	6.74117E-28	6.836E-28	1.41
16	14	120	7.25116E-31	13	1	7.25602E-31	7.324E-31	0.94
16	15	16	4.8584E-34	14	1	4.85992E-34	4.883E-34	0.47
16	16	1	1.52588E-37	15	1	1.52588E-37	1.526E-37	0.00

Availability Approximation (a = .995)

Table A-1

Figur   16